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# Menace of Spiralling Whitefly, *Aleurodicus dispersus* Russell on the Agrarian Community

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**A B S T R A C T**

Spiralling whitefly, *Aleurodicus dispersus* Russell, a polyphagous pest native to the Caribbean region and Central America has turned out to be cosmopolitan as well creating havoc to the farming community. The peculiar egg-laying pattern of this pest has given its name spiralling whitefly. The insect has four nymphal stages and has a pupal period of 2-3 days, thereby the total developmental period is of 18 to 23 days. It has been found that high temperature and high relative humidity during summer has a positive impact on pest incidence. As their body is covered with a heavy waxy material, management of this pest is quite a task. Since *A. dispersus* is an exotic pest in most of the countries, hence classical biological control through the introduction of natural enemies from the area of origin of the pest is considered as a sustainable management option. The natural enemies chiefly the parasitoids *Encarsia guadeloupae* Viggiani and *Encarsia haitiensis* Dozier has turned out to be a promising tool in suppressing the menace of spiralling whitefly.

## Introduction

The spiralling whitefly, *Aleurodicus dispersus* Russell causes various threats to several agricultural and horticultural crops both within the glasshouse and field conditions in India. *Aleurodicus dispersus* Russell (Aleyrodidae) is an exceptionally polyphagous pest and belong to the Caribbean region and Central America (Russell, 1965), where it is known from a wide range of host plants, but not regarded as a pest (Waterhouse and Norris, 1989). Worldwide it is commonly known as 'spiralling whitefly' because it lays eggs in a particular spiral pattern (Kumashiro *et al.,* 1983). It was introduced and assumed pest status in the Canary Islands in 1962 and Hawaii in 1978 (Paulson and Kumashiro, 1985), in American Samoa and Guam in 1981 (Firman, 1982) and then in most of the Pacific islands (Waterhouse and Norris, 1989).

The whitefly later spread westwards into several regions including Africa (Akinlosotu *et al.*, 1993; M'Boob and van Oers, 1994; Neuenschwander, 1994), Asia (Anon., 1987;

Wijesekera and Kudagamage, 1990; Kajita *et al.*, 1991; Wen *et al.*, 1994; Palaniswami *et al.*, 1995) and Australia (Carver and Reid, 1996; Lambkin, 1998).

In South Asia, it is presently found in Bangladesh (Scanlan, 1995), Sri Lanka (Wijesekera and Kudagamage, 1990), the Maldives (Martin, 1990) and India (Palaniswami *et al.*, 1995). In India, it was first recorded in 1993 at Thiruvananthapuram, Kerala on tapioca (Palaniswami *et al.*, 1995) and later it was observed in Tamil Nadu (David and Regu, 1995; Sivaprakasam and Chandramohan, 1997), Karnataka (Mani and Krishnamoorthy, 1996), Andhra Pradesh (Reddy and Chandarkar, 1999), Maharashtra (Sathe, 1999), Lakshadweep islands (Ramani, 2000) and of late Orissa and North East Region. There is no concrete evidence regarding its mode of entry into India or the country from which it was introduced, but it probably came from Sri Lanka (Ranjith *et al.*, 1996) or the Maldives (Muniappan, 1996). Spiralling whitefly was found in all the districts except Nilgiris in Tamil Nadu. The intensity of spiralling whitefly was more in Central and Southern Tamil Nadu (Geetha, 2000), while it was found in all the districts of Karnataka (Anon., 2001).

Nymphs and adults suck the sap from the leaves causing damage to several crops particularly cassava, chillies, mulberry, guava, banana, papaya, groundnut etc. in peninsular India (Mani and Krishnamoorthy, 1999a).

It is difficult to kill pest with conventional insecticides as they are covered with heavy waxy flocculent materials. But the natural enemies chiefly the parasitoids *Encarsia guadeloupae* Viggiani and *Encarsia haitiensis* Dozier proved to be highly useful in suppressing the spiralling whitefly in Pacific Islands, African and Asian countries (Mani and Krishnamoorthy, 2002) (Table 1–4).

## Biology

The common name of *A. dispersus*, the spiralling whitefly, is derived from this characteristic egg-laying pattern, although other species of aleurodicine whitefly also lay eggs in spiral patterns (Martin, 1990). Female whitefly lays yellowish-white eggs, which hatch in 7 days (Ragumoorthy and Kempraj, 1996) and 4-6 days (Palaniswami *et al.*, 1995) and 5-8 days (Geetha, 2000). Fecundity ranges from 51.8 to 64.06 eggs/female (Mallapanavar, 2000). The eggs are laid singly at right angles to the leaf veins on spiral deposits of wax (Ramani and Bhumannavar, 2001). There are four nymphal instars, which are greenish, white and oval. The four nymphal instars pass through 2.15-6.50, 2.7-5.00, 2.9-5.96 and 6.5-8.1 days, respectively (Geetha, 2000). Fourth instar nymphs are covered with heavy wax material. The total nymphal period normally lasts for 12 to 14 days and the pupal period lasts for 2 to 3 days (Palaniswami *et al.*, 1995). Thus, the development from egg to adult takes 18 to 23 days (Palaniswami *et al.*, 1995) and 22.5-29.66 days (Geetha, 2000). Adults are larger with dark reddish-brown eyes and fore wings with characteristic dark spots. Adults live for about 2 weeks and are particularly active during morning hours. All the stages of whitefly can produce extra-cuticular waxes that cover the body (Ramani and Bhumannavar, 2001).

## Ecology

The infestation of whiteflies is related to weather conditions (Mani, 2010). Heavy sporadic rains and cool temperatures result in a temporary reduction in *A. dispersus* population. However, dry conditions following rainfall between November and April, when both temperature and R.H. are high, favours pest outbreak (Palaniswami *et al.*, 1995). According to Ranjith *et al.*, (1996), the whitefly had increased in number

drastically in summer and decreased after the pre-monsoon showers in Kerala. The pest incidence on mulberry was high during April-June in and around Bangalore (Narayanaswamy and Ramegowda, 1999). *A. dispersus* exhibited maximum infestation (19.44 PPI) in April (summer), lowest in September (0.79 PPI) and moderate in November (2.58 PPI)) on mulberry. The mulberry was free from this pest from August to October, which coincided with Kharif rains (Jagadish *et al.,* 2003; Hemalatha and Shree, 2008). In Karnataka, the population of spiralling whitefly was found to be high during March-June and the density of the whitefly was positively correlated with maximum temperature and negatively correlated with relative humidity on guava (Mani and Krishamoorthy, 2000; Mallapanavar, 2000). Gopi *et al.,* (2001a) found the incidence of spiralling whitefly to be higher during November-February in Coimbatore. A similar trend was observed around Pune and Hyderabad (Mani *et al.,* 2000b). The nymphal population was low in June-July and reached a peak in November at Shimoga (Aiswariya *et al.,* 2007b).

## Host range

Being polyphagous, *A. dispersus* is known to attack about 500 plants in different countries (Mware *et al.,* 2010) and 280 in India alone (Ramani *et al.,* 2002; Mani, 2010). Douressamy *et al.,* (1997) and Rajadurai and Thiagarajan (2003) have recorded the incidence on 38 genera of plants belonging to 27 families and above 100 species. *A. dispersus* was recorded on the plant species numbering 25 (David and Regu, 1995), 70 (Prathapan, 1996) and 22 (Ranjith *et al.,* 1996) and 45 (Mani and Krishnamoorthy, 1999a), 27 (Gajendra Babu and David, 1999), 53 (Mariam *et al.,* 2000), 27 (Ramani, 2000), 128 (Geetha and Swamiappan, 2001a), 94 (Muralikrishna, 1999), 102 (Mallapanavar, 2000) and 68 (Srinivasa, 2000) and 99 (Aiswariya *et al.,* 2007a). The major host plants of economic concern in India are banana, guava, avocado, papaya, coconut, cucurbits, dahlia, gerbera, gladiolus, tomato, mulberry, tapioca and bell pepper, in addition to several species of shade trees in the urban environment. The families Fabaceae, Asteraceae, Malvaceae, Myrtaceae, Euphorbiaceae and Moraceae seem to contain the most species of host plants (Srinivasa, 2000; Geetha and Swamiappan, 2001a).

## Damage and loss

Nymphs and adults congregate generally on the lower surface, but sometimes on the upper surface of leaves of the host plants, stem (cassia) and fruits (papaya) and suck the sap. Wen *et al.,* (1995) reported a loss in fruit yield of 80% in guava attacked by the pest for four months consecutively in Taiwan, but estimates of yield loss due to this pest are not available in India. Ranjith *et al.,* (1996) observed severe damage to many crops in Kerala and Geetha *et al.,* (1998) observed severe incidence in a groundnut crop in Tamil Nadu. Heavy incidence of the whitefly caused yield reduction to an extent of 53.10% in tapioca (Geetha, 2000). Injury caused by heavy infestations was usually insufficient to kill the plants (Nambiar, 1997). Adverse impacts, such as longer larval duration, decreased food conversion and utilization and reduction in economic parameters of the cocoon, were noticed when the whitefly-infested mulberry leaves were fed to the silkworm, *Bombyx mori* (L.) (Lepidoptera, Bombycidae), due to reduced nutrition levels in affected leaves (Mariam, 1999; Ahamed *et al.,* 1999; Narayanaswamy *et al.,* 1999). Severe infestation of spiralling whitefly reduces the quality of banana leaves commonly used to serve the food in all the functions in South India (Mani *et al.,* 2003). In Kerala, chillies were found to be damaged

by the spiralling whitefly (Beevi and Lyla, 2001). Heavy incidence of spiralling whitefly was observed on coconut during March-May 2000 in Madurai (Razak, 2002) and attack by these pest causes unseasonal leaf fall and consequent yield reduction in rubber (Ranjith *et al.*, 1996).

Adults and nymphs of the whitefly cause damage by direct feeding on plant sap and when present in very large numbers can cause leaf fall, but even heavy infestations are insufficient to kill the plants. The copious white, waxy, flocculent material secreted by all the stages of the pest is readily spread by wind, creating a nuisance. Honeydew excreted by the nymphs encourages the growth of sooty mould on leaf surfaces, reducing the photosynthetic capacity of the plant (Kumashiro *et al.*, 1983). The sticky honeydew carried by the wind on the flocculant wax adheres to windows and cars and causes considerable annoyances. Complaints were received for allergies and dermatitis.

## Management

Management of whitefly is indeed a difficult task owing to the number of wild-grown host plants that support the build-up of the pest. Populations of this insect thrive in warm, dry weather.

**Table.1** Common host plants of *A. dispersus* in India

| Botanical name | Common name | Family |
|---|---|---|
| ***Abelmoschus esculentus*** | Lady's finger | Malvaceae |
| ***Capsicum annum*** | Capsicum/Bell pepper | Solanaceae |
| ***Coccinia indica*** | Coccinia | Cucurbitaceae |
| ***Cucurbita maxima*** | Winter squash | Cucurbitaceae |
| ***Ipomoea batata*** | Sweet potato | Convolvulaceae |
| ***Solanum lycopersicum*** | Tomato | Solanaceae |
| ***Manihot esculenta*** | Tapioca | Euphorbiaceae |
| ***Moringa* sp.** | Drum stick | Moringaceae |
| ***Phaseolus vulgaris*** | Kidney bean | Fabaceae |
| ***Solanum melongena*** | Brinjal | Solanaceae |
| ***Arachis hypogaea*** | Groundnut | Fabaceae |
| ***Cocos nucifera*** | Coconut | Arecaceae |
| ***Glycine max*** | Soybean | Fabaceae |
| ***Ricinus communis*** | Castor | Euphorbiaceae |
| ***Gossypium* spp.** | Cotton | Malvaceae |
| ***Annona squamosa*** | Custard apple | Annonaceae |
| ***Artocarpus heterophyllus*** | Jack fruit | Moraceae |
| ***Carica papaya*** | Papaya | Caricaceae |
| ***Citrus sinensis*** | Sweet lemon | Rutaceae |
| ***Emblica officinalis*** | Indian gooseberry | Euphorbiaceae |
| ***Ficus racemosa*** | Fig | Moraceae |
| ***Mangifera indica*** | Mango | Anacardiaceae |
| ***Manilkara zapota*** | Sapota | Sapotaceae |
| ***Musa* spp.** | Banana | Musaceae |

| | | |
|---|---|---|
| ***Persea americana*** | Avacado | Lauraceae |
| ***Psidium guajava*** | Guava | Myrtaceae |
| ***Punica granatum*** | Pomegranate | Lythraceae |
| ***Syzygium jambos*** | Rose apple | Myrtaceae |
| ***Terminalia catappa*** | Almond | Combretaceae |
| ***Vitis vinifera*** | Grapes | Vitaceae |
| ***Dahlia* sp.** | Dahlia | Asteraceae |
| ***Ficus elastica*** | Rubber tree | Moraceae |
| ***Gerbera* sp.** | Gerbera | Asteraceae |
| ***Gladiolus* sp.** | Gladiolus | Amaryllidaceae |
| ***Hibiscus* spp.** | Hibiscus | Malvaceae |
| ***Rose indica*** | Rose | Rosaceae |
| ***Anacardium occidentale*** | Cashew | Anacardiaceae |
| ***Areca catechu*** | Areca nut | Arecaceae |
| ***Coffea arabica*** | Coffee | Rubiaceae |
| ***Piper betel*** | Betel leaf plant | Piperaceae |
| ***Jatropha* sp.** | Jatropha | Euphorbiaceae |
| ***Cajanus cajan*** | Pigeon pea | Fabaceae |
| ***Lantana camara*** | Lantana | Verbenaceae |
| ***Phaseolus vulgaris*** | Beans | Fabaceae |
| ***Sesbania grandiflora*** | Agathi | Fabaceae |
| ***Azadirachta indica*** | Neem | Meliaceae |
| ***Piper nigrum*** | Pepper | Piperaceae |
| ***Santalum album*** | Sandal | Santalaceae |
| ***Eucalyptus* sp.** | Eucalyptus | Myrtaceae |

(Ramani *et al*., 2002; Hodges and Evans, 2007; Mani, 2010; Kumari, 2011)

**Table.2** Parasitoids of Spiralling whitefly, *Aleurodicus dispersus* in India

| Parasitoids | Family and Order | Reference |
|---|---|---|
| ***Encarsia haitiensis* Dozier (=*Encarsia meritoria* Gahan)** | Aphelinidae Hymenoptera | Anon., (2000) Srinivasa *et al.* (1999); Beevi *et al.* (1999); Mani *et al.* (2001); Geetha and Swamiappan, 2001b) |
| ***Encarsia guadeloupae* Viggiani** | Aphelinidae Hymenoptera | Mani *et al.* (2001); Beevi and Lyla (2001) |
| ***Leptus* sp.** | Erythraeidae Acarina | Geetha and Swamiappan (2001c) |

**Table.3** Predators of Spiralling whitefly, *Aleurodicus dispersus* in India

| Predator | Family and Order | Reference |
|---|---|---|
| ***Axinoscymnus puttarudiahi*** | Coccinellidae, Coleoptera | Mani and Krishnamoorthy (1999a, c) Mariam (1999); Muralikrishna (1999) |
| ***Curinus coeruleus* Muls.** | Coccinellidae, Coleoptera | Mani *et al.* (2001) |
| ***Horniolus* sp.** | Coccinellidae, Coleoptera | Anon., (2002) |
| ***Cheilomenes sexmaculata* (Fab.)** | Coccinellidae, Coleoptera | Palaniswami *et al.* (1995)<br>Mani and Krishnamoorthy (1999a)<br>Mariam (1999); Muralikrishna (1999)<br>Geetha (2000) |
| ***Cryptolaemus montrouzieri* Muls** | Coccinellidae, Coleoptera | Mani and Krishnamoorthy (1999a)<br>Muralikrishna (1999)<br>Geetha (2000) |
| ***Chilocorus nigrita* (Fab.)** | Coccinellidae, Coleoptera | Mani and Krishnamoorthy (1999b)<br>Geetha (2000) |
| ***Anegleis cardoni* (Wiese)** | Coccinellidae, Coleoptera | Mani *et al.* (2001)<br>Mariam (1999);<br>Geetha (2000) |
| ***Anegleis perrotteti* (Muls.)** | Coccinellidae, Coleoptera | Anon. (2002) |
| ***Jauravia dorsalis* (Wise.)** | Coccinellidae, Coleoptera | Anon. (2002) |
| ***Jauravia pallidula* Motseh** | Coccinellidae, Coleoptera | Anon. (2002) |
| ***Rodolia amabilis* Kapur** | Coccinellidae, Coleoptera | Anon. (2002) |
| ***Rodoloia breviuscula* Weise** | Coccinellidae, Coleoptera | Anon. (2002)<br>Geetha (2000) |
| ***Rodolia fumida* Mulsant** | Coccinellidae, Coleoptera | Anon. (2002); Geetha (2000) |
| ***Serangium parcesetosum* Sic** | Coccinellidae, Coleoptera | Mani *et al.* (2000a) |
| ***Nephus regularis* Sic** | Coccinellidae, Coleoptera | Anon. (2001) |
| ***Scymnus* sp.** | Coccinellidae, Coleoptera | Anon. (2000) |
| ***Psedoscymnus* sp.** | Coccinellidae, Coleoptera | Anon. (2000) |
| ***Keiscymnus* sp.** | Coccinellidae, Coleoptera | Anon. (2000) |
| ***Scymnus coccivora* Ayyar** | Coccinellidae, Coleoptera | Anon. (2002) |
| ***Scymnus latemaculatus* Motsch.** | Coccinellidae, Coleoptera | Anon. (2002); Geetha (2000) |
| ***Scymnus posticalis* Sic** | Coccinellidae, Coleoptera | Anon. (2002) |

| | | |
|---|---|---|
| ***Scymnus saciformis* Motsch.** | Coccinellidae, Coleoptera | Anon. (2002) |
| ***Scymnus nubilus* Muls.** | Coccinellidae, Coleoptera | Anon. (2000) |
| ***Pseudaspidimerus flaviceps* (Walk.)** | Coccinellidae, Coleoptera | Anon. (2002) |
| ***Pseudaspidimerus trinotatus* (Walk.)** | Coccinellidae, Coleoptera | Anon. (2001) |
| ***Cybocephalus* sp.** | Nitidulidae, Coleoptera | Mani and Krishnamoorthy (2001)<br>Muralikrishna (1999)<br>Geetha (2000) |
| ***Mallada astur* (Banks)** | Chrysopidae, Neuroptera | Mani and Krishnamoorthy (1999a)<br>Mariam (1999);<br>Geetha (2000) |
| ***Apertochrysa* sp.** | Chrysopidae, Neuroptera | Mani and Krishnamoorthy (1999a)<br>Geetha *et al.* (1999) |
| ***Nobilinus* sp.** | Chrysopidae, Neuroptera | Mani and Krishnamoorthy (1999a) |
| ***Mallada boninensis* (Okomato)** | Chrysopidae, Neuroptera | Mani and Krishnamoorthy (1999a) |
| ***Chrsoperla carnea* (Steph)** | Chrysopidae, Neuroptera | Geetha *et al.* (2000) |
| ***Symherobius barberi* (Banks)** | Hemerobiidae, Neuroptera | Paulson and Kumashiro (1985) |
| ***Hemerobius* sp.** | Hemerobiidae, Neuroptera | Mani *et al.* (2001) |
| ***Notiobiella viridinervis* Banks** | Hemerobiidae, Neuroptera | Mani *et al.* (2001) |
| ***Leucopis* sp.** | Chamaemyiidae, Diptera | Anon. (2000) |
| ***Triommato coccdivora* (Felt)** | Cecidomiidae, Diptera | Mani and Krishnamoorthy (1999a) |
| ***Acletoxenus indicus* Malloch** | Drosophilidae, Diptera | Mani and Krishnamoorthy (1999a) |
| ***Spalgis epeus* (West wood)** | Lycaenidae, Lepidoptera | Mani *et al.* (2001) |
| ***Oecophylla smaragdina* (F)** | Formicidae, Hymenoptera | Gopi *et al.* (2001a) |
| ***Solenopsis geminata* (F)** | Formicidae, Hymenoptera | Gopi *et al.* (2001a) |
| ***Oxopes* sp.** | Oxypidae, Acari | Geetha (2000) |
| **House sparrow, *Passer domesticus* (L)** | Aves | Gopi *et al.* (2001a) |
| **Spiderhunter, *Archnothera longirostris* (Latham)** | Aves | Gopi *et al.* (2001a) |
| **Pied bushchat, *Saxicola caprata* (L)** | Aves | Gopi *et al.* (2001a) |
| **Tailor bird, *Orthotomus sutorius*** | Aves | Gopi *et al.* (2001a) |

**Table.4** Pathogens of spiralling whitefly, *Aleurodicus dispersus* in India

| Pathogen | Family and Order | Reference |
|---|---|---|
| ***Pacilomyces farinosus* (Brown and Smith)** | Moniliales, Deutromycetes | Mani *et al.* (2001) |
| ***Verticillium lecanii* Zimm.** | Moniliales, Deutromycetes | Mallappanavar (2000) |

Heavy rains and cool temperatures may result in a temporary reduction of spiralling whitefly populations (Waterhouse and Norris, 1989). In countries where it has been introduced, chemical and biological control methods have been tried. This pest has been found susceptible to insecticides and neem oil in several countries (Wijesekera and Kudagamage, 1990; Wen *et al.*, 1995; Alam *et al.*, 1998). Tobacco extract, neem oil, fish oil, rosin soap and detergent solution with several insecticides have been found effective in India (Ranjith *et al.*, 1996; Mariam, 1999; Muralikrishna, 1999; Geetha, 2000).

Spraying a dilute aqueous solution of detergent has been suggested to reduce infestations (Waterhouse and Norris, 1989). The use of light traps covered with Vaseline coating has been used to trap the adults (Srinivasan and Mohanasundaram, 1997). As *A. dispersus* is an exotic pest in most countries, classical biological control through the introduction of natural enemies from the area of origin of the pest is considered the best option for a sustainable solution (Lopez *et al.*, 1997a).

## Cultural control

Use of clean planting material delays the appearance of the whitefly population. Pruning the heavily infested trees and shrubs was recommended to minimize the spiralling whitefly incidence. After the pruning, the population rapidly increased within 4-5 months on guava (Geetha, 2000).

## Physical control

The light trap was progressively suitable apparatus for monitoring the whitefly population. Use of light traps covered with Vaseline coating to rap adults have been suggested (Srinivasan and Mohanasundaram, 1997). Fluorescent light smeared with castor oil attracted and trapped a large number of adults (Mariam, 1999). Maximum adults were attracted and caught in yellow colour sticky trap (Geetha, 2000).

## Chemical control

The whitefly can build up a resistance to most chemical pesticides and should not be treated with these. Spraying with chemicals also destroys natural enemies or biological control agents that have been released. Application of chemicals to the lower surface of infested leaves thoroughly reduces the whitefly abundance but temporarily. Muralikrishna in 1999 reported that Tobacco extract (4%,) was found effective in minimising the spiralling whitefly. Spraying of neem oil (2%), fish oil rosin soap (4%) and detergent soap solution (5%) reduces the whitefly population (Ranjith *et al.*, 1996; Mariam, 1999 and Geetha, 2000). Contact insecticides like malathion and carbaryl at 0.10% were also found effective against young nymphs (Ragumoorthy and Kempraj, 1996). Dichlorvos 0.08% was found toxic to various stages of spiralling whitefly (Mariam, 1999). Triazophos 0.08% and phosalone 0.07% were equally effective against spiralling whitefly (Geetha, 2000; Mallapanavar, 2000). Application of neem oil 2% and neem seed kernel extract 3% were

found to be effective in suppressing the nymphal and adult whitefly population (Kirubavathy *et al.,* 1999). Triazophos at 0.03% was found to be highly effective against spiralling whitefly (Kambrekar and Awaknavar, 2004). According to Dubey and Sundararaj (2004), Chorpyriphos at 0.04% was found to effective against *A. dispersus.*

## Biological control

As *A. dispersus* is an exotic pest in most countries, classical biological control is considered to be the best option for a sustainable solution (Lopez *et al.,* 1997a). In Hawaii, several Pacific islands, the Maldives, Taiwan and Tenerife (Canary Islands), biological control has been attempted by introducing natural enemies (aphelinids and coccinellids) from the Caribbean region or from other areas where the parasitoids have been introduced earlier and substantial control has been achieved (Kumashiro *et al.,* 1983; Waterhouse and Norris, 1989; Greathead and Greathead, 1992; Chien *et al.,* 2000; Nijhof *et al.,* 2000). The aphelinid parasitoids *Encarsia haitiensis* and *Encarsia guadeloupae* have given excellent control of spiralling whitefly in several countries Malaysia, Philippines, Benin, Togo, Ghana, Nigeria Guam, Taiwan, Australia, Hawaii and some other Pacific islands (Waterhouse and Norris, 1989; D'Almeida *et al.,* 1998; Mani and Krishnamoorthy, 2002). The natural predator complex did not have any significant effect on the spiralling whitefly populations as witnessed in many countries. Inundative releases of *Cryptolaemus motrouzieri* and *Mallada astur* against *A. dispersus* had only in temporary reduction of the whiteflies during 1998-1999 in Karnataka (Mani *et al.,* 2001). *Verticillium lecanii* (Zimm) @ 1.33 x $10^7$ and Verticel @ 7.5 g/l were found to be most effective against spiralling whitefly 7,15 and 21 days after spraying (Mallappanavar, 2000).

## Natural enemies

In addition to the accidentally introduced aphelinids, several indigenous natural enemies have expanded their host range to this invading pest in India (Palaniswami *et al.,* 1995; Mani and Krishnamoorthy, 1999a, b; PDBC, 2000; Ramani, 2000; Mani and Krishnamoorthy, 2000; Mani *et al.,* 2000a; PDBC, 2001; Geetha and Swamiappan, 2001a). As many as 62 natural enemies have been recorded attacking *A. dispersus* in Trinidad, Columbia, Hawaii, Guam, Indonesia, Sri Lanka, Malaysia, Benin, Togo, Ghana, Nigeria, Philippines, Florida, Fiji, Pohnpei, Costa Rica and India.

## Parasitoids

Two aphelinid parasitoids have been accidentally introduced along with the host. In Minicoy islands, the whitefly nymphs were found parasitised by aphelinids, which were identified later as *Encarsia haitiensis* and *E. guadeloupae* (Ramani, 2000). In the mainland, Beevi *et al.,* (1999) recorded *Encarsia* sp. for the first time in January 1998 which was closer to *Encarsia meritoria* Gahan on spiralling whitefly in Thrissur, Kerala. Srinivasa *et al.,* (1999) reported a species of *Encarsia*, which was closely related to *E. haitiensis* and E. *meritoria* on spiralling whitefly in February in Bangalore. Geetha and Swamiappan (2001c) also recorded *Encarsia* sp., which was closer to *E. meritoria* on spiralling whitefly during December 1998 around Coimbatore. *Encarsia* species reported by Srinivasa *et al.,* (1999), Beevi *et al.,* (1999) and Geetha and Swamiappan (2001c) appeared to be *Encarsia haitiensis*, which is closely related to or possibly conspecific with, *E. meritoria* (D'Almeida *et al.,* 1998). The exploratory survey carried out around Thrissur and Thiruvananthapuram during February 2000 in Kerala yielded a large number of *Encarsia haitiensis* (Mani *et al.,* 2000a).

## Predators

More than 40 indigenous predators, mostly generalists and few host-specific species, have been recorded in India (Ramani *et al.*, 2002). The major predators are neuropterans (chrysopids, hemerobiids and an unidentified coniopterygid), a new species of nititulid beetle, *Cybocephalus* sp. and several coccinellids. Many coccinellid predators and aphelinid parasitoids (*Encarsia* spp.) were found on whitefly species in Trinidad and some were utilized for classical biological control in Hawaii and other regions (Cock, 1985; Kumashiro *et al.*, 1983). Lopez *et al.*, (1997b) found three species of the coccinellid *Nephaspis* and several generalist predators including syrphids, chrysopids, spiders and ants preying on whitefly in Trinidad and Tobago. *Cybocephalus* sp. was recorded for the first time from Minicoy (Ramani, 2000) and later found commonly occurring in and around Bangalore, in association with the whitefly almost throughout the year, especially at high host densities (PDBC, 2000; Mani and Krishnamoorthy, 2000; PDBC, 2001). *Cybocephalus* spp. are known to be mainly predators of diaspine scales (Blumberg and Swirski, 1982), but some species like *Cybocephalus aleyrodiphagus* on *Orchamoplatus citri* (Takahashi) (Kirejtshuk *et al.*, 1997) and this species have been recorded preying on whiteflies.

Out of the 26 species of coccinellids, the ones commonly found in the spiralling whitefly colonies are *Anegleis cardoni* (Weise), *Anegleis perrotteti* (Mulsant), *Axinoscymnus puttarudriahi*, *Cheilomenes sexmaculata* (F), three species of *Jauravia*, *Nephus regularis* (Sicard), *Pseudoscymnus* sp., *Pseudaspidimerus flaviceps* (Walker) *Pseudaspidimerus trinotatus* (Thunberg), and *Scymnus saciformis* Motschulsky. *Scymnus* sp. was recorded as a common predator in Costa Rica (Metzler and Laprade, 1998). *Axinoscymnus* sp. and *C. sexmaculata* have also been found in Indonesia (Kajita *et al.*, 1991) and *A. puttarudriahi* was found feeding on the eggs of the whitefly in Sri Lanka (Wijesekera and Kudagamage, 1990).

Mani and Krishnamoorthy (1997) found that the naturalized Australian ladybird beetle, *Cryptolaemus montrouzieri* Mulsant preyed on the whitefly almost throughout the year, but had little effect in reducing the pest population. Mani and Krishnamoorthy (1999b) and Geetha and Swamiappan (2001c) have also studied the predatory potential and developmental period of *C. montrouzieri* on the whitefly in the laboratory. It was also recorded in Hawaii (Paulson and Kumashiro, 1985). *Cryptolaemus montrouzieri* mainly feeds on pseudococcids and may in all probability be an incidental record in mixed infestations of whiteflies and pseudococcids, especially those containing *Ferrisia virgata* (Cockerell). *Curinus coeruleus* (Mulsant) has been recorded feeding on *A. dispersus* in India (Mani *et al.*, 2000a; PDBC, 2001) and also in Hawaii (Waterhouse and Norris, 1989) and the Philippines (Villacarlos and Robin, 1992). Several birds, ants and spiders have also been recorded feeding on *A. dispersus* in India (Gopi *et al.*, 2001b).

## Pathogens

The only pathogen recorded on *A. dispersus* has been *Paecilomyces farinosus* (Holm.) Brown and Smith from areas near Bangalore (Mani *et al.*, 2000a; PDBC, 2001).

In conclusion the *Aleurodicus dispersus* is capable of spreading very fast from one location to another location. In the next few years, the spiralling whitefly may well be discovered in many more states in India. Available evidence suggests that new infestations have often resulted from transportations of infested plants. Chemical

control is not practicable because of the abundance of host plants including some large size avenue trees and widespread distribution. With the accidental introduction of both species of *Encarsia* into India, a visible reduction in the population of *A. dispersus* has been noticed in Minicoy, Agatti and Kavaratti islands of Lakshadweep, Karnataka and Kerala, similar to that witnessed in Hawaii, Guam and other Pacific islands, West Africa and Tenerife. In south Asia, *A. dispersus* has been reported from Bangladesh, Sri Lanka and the Maldives in addition to India, but the two introduced aphelinid parasitoids have not been so far reported from Sri Lanka and Bangladesh. The impact of the accidental introductions of the parasitoids in conjunction with the indigenous natural enemies, on the whitefly populations, has to be carefully assessed in India, before any further introductions are considered.

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